APPENDIX A

PLANT-MIX COLD-LAID BITUMINOUS PAVEMENTS, DESIGN AND CONTROL

A-1. General.

a. Alternate approaches. It is anticipated that under emergency mobilization conditions bituminous pavement materials will be supplied by local sources. In most cases these sources have been utilized by Federal or state agencies in the past and have approved design mixes available to meet the needs as outlined in this manual. Review of the available mix results along with associated material test results and supplemented by field inspection and testing of present materials should supply sufficient information to proceed with design and construction. The following discussion is presented to provide the designer with design requirements as an aid to evaluating available materials and to provide information on methods of obtaining design data if not locally available.

b. Procedures and criteria. Procedures and criteria described in this appendix are applicable to the design and control of plant-mix cold-laid bituminous pavements using asphalt cement and liquefier, liquid asphalt, emulsified asphalt, or tar.

A-2. Design.

a. Preliminary work. A survey of the materials available in suitable quantities for use in construction of the pavement is the first step in the design of a paving mixture. Materials normally required for the paving mix are coarse aggregate, fine aggregate, mineral filler, and bitumen.

b. Sampling. Test reports reflecting the results of sampling and testing of the aggregates in bituminous materials will be necessary prior to design. Sufficient quantities of materials are to be obtained at time of sampling to meet the ASTM requirements and for laboratory pavement design tests subsequently described. Normally, 200 pounds of aggregates will produce the desired gradation and 5 gallons of bitumen will produce sufficient data during testing.

c. Tests on aggregates. Aggregates for use in bituminous pavements should be clean, hard, and durable. Aggregates that are angular in shape generally provide more stable pavements than do rounded aggregates. Most of the tests of aggregates required in the design of hot-mix, hot-laid bituminous concrete are also applicable to the cold-laid type. Therefore, many of the tests of EM 1110-3-141 appendix A will be referenced.

(1) Sieve analysis. A sieve analysis of the aggregates considered for use in a paving mix has the following advantages. An

experienced engineer can obtain general information from the grading curve as to the suitability of the aggregate for a paving mix, the quantity of bitumen required, and whether or not mineral filler should be added. Also, a sieve analysis is required if the aggregate is to be used in laboratory tests for paving mix design, as described later. Sieve analyses of fine and coarse aggregates should be in accordance with ASTM C 136. Figure A-1 is a form suggested for use in recording and calculating data obtained from laboratory sieve analyses. Mechanical analysis data for typical coarse aggregate, fine aggregate, sand, and mineral filler used in a paving mixture are shown in figure A-1.

(2) Specific gravity. Specific gravity values for aggregates used in a paving mix are required in the computation of percent voids total mix and percent voids filled with bitumen in the compacted specimens. Criteria have been established to furnish limiting values for these factors. However, specific gravity values must be determined with care and in accordance with specified procedures in order that application of the criteria will be valid. Two different specific gravity determinations are provided, and the selection of the appropriate test procedure depends on the water absorption of each aggregate blend.

(3) Wear requirements for coarse aggregates. The determination of percentage of wear for coarse aggregates may not be necessary if the aggregate has been found satisfactory by previous tests. However, coarse aggregates obtained from new or doubtful deposits can be tested for conformance to specification requirements using ASTM C 131.

d. Tests on mineral filler. Some mineral fillers have been found to be more satisfactory in asphalt paving mixtures than others. For example, fine sands and clays are normally less suitable fillers than limestone filler or portland cement. Well-graded materials are more suitable than poorly graded materials. The gradation of the mineral filler can be as determined by use of ASTM D 422. The specific gravity of the mineral filler is required in void computation and can be determined by testing except that when the bulk-impregnated specific gravity is used and the mineral filler is included in the blended aggregate. Figure A-2 is a form suggested for tabulation and computation of these data; typical data have been entered in this form to illustrate its use.

e. Tests on bituminous materials. The specific gravity of the bituminous material is necessary in determining the percent by volume of bituminous materials in the mix. Since only the residual asphalt will be used in calculating the percent binder, the amount of residual asphalt cement in liquid asphalts and asphalt emulsions must be determined in addition to residual asphalt or asphalt cement.

SIEVE ANALYSIS

JOB NO:	PROJECT: TYPICAL MIX	DATE:

STOCKPILE SAMPLES DRY GRADATION

SAMPLE NO. Crushed Coarse Aggregate

U.S. STAND. SIEVE NO.	WEIGHT RETAINED	% RETAINED	% PASS
3/4			100
1/2	225.9	30.0	70.0
3/8	267.3	35.5	34.5
NO. 4	237.2	31.5	3.0
NO. 8	22.6	3.0	
NO. 16			
NO. 30			
NO. 50			
NO. 100			
NO. 200			
-200			
TOTAL	753.0		

WEIGHT ORIGINAL SAMPLE

SAMPLE NO. Crushed Fine Aggregate

U.S. STAND. SIEVE NO.	WEIGHT RETAINED	% RETAINED	% PASS
3/4			
1/2			100
3/8	1.1	0.2	99.8
NO. 4	53.9	9.8	90.0
NO. 8	104.6	19.0	71.0
NO. 16	104.6	19.0	52.0
NO. 30	96.3	17.5	34.5
NO. 50	82.5	15.0	19.5
NO. 100	60.5	11.0	8.5
NO. 200	30.3	5.5	3.0
-200	16.5	3.0	
TOTAL	550.3		

WEIGHT ORIGINAL SAMPLE

WASHED GRADATION

SAMPLE NO. Natural Sand

U.S. STAND. SIEVE NO.	WEIGHT RETAINED	% RETAINED	% PASS
3/4			
1/2			
3/8			
NO. 4			
NO. 8			
NO. 16			
NO. 30			100
NO. 50	9.4	4.5	95.5
NO. 100	54.6	26.0	69.5
NO. 200	124.9	59.5	10.0
-200 (T)	21.0	10.0	
TOTAL	209.9		

(A) WEIGHT ORIGINAL SAMPLE 209.2 GM
(B) WEIGHT AFTER WASHED 193.7 GM
(C) WASH LOSS (A - B) 15.5 GM
(S) -200 FROM SIEVING 5.5 GM
(T) TOTAL -200 C + S 21.0 GM
USE "T" TO CALCULATE PERCENTAGES

SAMPLE NO. Limestone Filler

U.S. STAND. SIEVE NO.	WEIGHT RETAINED	% RETAINED	% PASS
3/4			
1/2			
3/8			
NO. 4			
NO. 8			
NO. 16			
NO. 30			
NO. 50			100
NO. 100	2.3	2.0	98.0
NO. 200	9.4	8.0	90.0
-200 (T)	105.3	90.0	
TOTAL	117.0		

(A) WEIGHT ORIGINAL SAMPLE 117.4 GM
(B) WEIGHT AFTER WASHED 18.9 GM
(C) WASH LOSS (A - B) 98.5 GM
(S) -200 FROM SIEVING 6.8 GM
(T) TOTAL -2000 C + S 105.3 GM
USE "T" TO CALCULATE PERCENTAGES

TESTED BY:	COMPUTED BY:	CHECKED BY:

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FIGURE A-1. SIEVE ANAYSIS

SPECIFIC GRAVITY OF BITUMINOUS MIX COMPONENTS					DATE
PROJECT		JOB TYPICAL MIX			
COURSE AGGREGATE					
MATERIAL PASSING 3/4" SIEVE AND RETAINED ON 3/8" SIEVE	UNITS				
SAMPLE NUMBER Coarse aggregate					
1. WEIGHT OF OVEN - DRY AGGREGATE	GM.	378.3			
2. WEIGHT OF SATURATED AGGREGATE IN WATER	GM.	241.0			
3. DIFFERENCE (1.-2.)	GM.	137.3			
APPARENT SPECIFIC GRAVITY, $G = \frac{(1.)}{(3.)}$	2.755				
FINE AGGREGATE					
MATERIAL PASSING NUMBER 3/8" SIEVE	UNITS				
SAMPLE NUMBER Natural sand					
4. WEIGHT OF OVEN - DRY MATERIAL	GM.	478.8			
5. WEIGHT OF FLASK FILLED WITH WATER AT 20°C	GM.	678.6			
6. SUM (4.+5.)	GM.	1157.4			
7. WEIGHT OF FLASK + AGGREGATE + WATER AT 20°C,	GM.	977.4			
8. DIFFERENCE (6.-7.)	GM.	180.0			
APPARENT SPECIFIC GRAVITY, $G = \left(\frac{4.}{8.}\right)$	2.660				
FILLER	UNITS				
SAMPLE NUMBER Limestone Filler					
9. WEIGHT OF OVEN - DRY MATERIAL	GM.	466.5			
10. WEIGHT OF FLASK FILLED WITH WATER AT 20°C,	GM.	676.1			
11. SUM (9.+10.)	GM.	1142.6			
12. WEIGHT OF FLASK + AGGREGATE + WATER AT 20°C,	GM.	973.8			
13. DIFFERENCE (11.-12.)	GM.	168.8			
APPARENT SPECIFIC GRAVITY, $G = \left(\frac{9.}{13.}\right)$	2.764				
BINDER	UNITS				
SAMPLE NUMBER 6873					
14. WEIGHT OF PYCNOMETER FILLED WITH WATER	GM.	61.9595			
15. WEIGHT OF EMPTY PYCNOMETER	GM.	37.9215			
16. WEIGHT OF WATER (14.-15.)	GM.	24.0380			
17. WEIGHT OF PYCNOMETER + BINDER	GM.	47.8617			
18. WEIGHT OF BINDER (17.-15.)	GM.	9.9402			
19. WEIGHT OF PYCNOMETER + BINDER + WATER TO FILL PYCNOMETER	GM.	62.1568			
20. WEIGHT OF WATER TO FILL PYCNOMETER (19.-17.)	GM.	47.8617			
21. WEIGHT OF WATER DISPLACED BY BINDER	GM.	9.7429			
APPARENT SPECIFIC GRAVITY, $G = \left(\frac{18.}{20.}\right)$	1.020				
REMARKS					
TECHNICIAN (Signature)	COMPUTED BY (Signature)		CHECKED BY (Signature)		

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FIGURE A-2. SPECIFIC GRAVITY OF BITUMINOUS MIX COMPONENTS

f. Selection of materials for mix design. The first step in the design of a paving mix is the tentative selection of materials. The bitumen used in the laboratory tests will be the same as that used in field construction. The selection of aggregates and mineral filler for the paving mix is more involved than the selection of the bitumen. Aggregates and mineral fillers that do not meet the requirements of the specifications should be eliminated from further consideration. The remaining aggregates and filler then must be examined from technical and economical viewpoints. The final objective is to determine the most economical blend of aggregates and mineral filler that will produce a pavement meeting the engineering requirements set forth in this manual. The mix design gradation (i.e., job-mix formula) plus or minus specification tolerances must fall within the specified gradation band. The job-mix formula will be allowed the tolerances specified in the guide specification.

(1) Aggregates and mineral filler. Generally, it is necessary to combine aggregates from two or more sources for paving mixes. The addition of mineral filler is sometimes required, depending on the amount of filler naturally present in the aggregate. Mathematical equations are available for making such combinations, but they are not presented herein because they are lengthy and normally it is easier to use trial-and-error procedures. The gradation of the aggregate must fall within the limits of the gradations chosen from table A-1 for the project and will present a smooth curve when plotted with sieve size versus percent passing.

Table A-1. Aggregate Gradations for Plant-Mix Cold-Laid Bituminous Pavements

Sieve Size	Percent Passing, by Weight	
	1/2-Inch Maximum	3/8-Inch Maximum
1/2 inch	100	
3/8 inch	86 ± 9	100
No. 4	66 ± 9	85 ± 9
No. 8	53 ± 9	71 ± 9
No. 16	41 ± 9	57 ± 9
No. 30	31 ± 9	43 ± 9
No. 50	21 ± 8	31 ± 8
No. 100	13 ± 6	19 ± 6
No. 200	4.5 ± 1.5	6 ± 3

(2) Bituminous materials. Plant-mix cold-laid pavements may be made with asphalt cement and liquefier, liquid asphalts, emulsified asphalts, or tar. The asphalt-cement-and-liquefier type is recommended because the wetting action of the liquefier insures good adhesion of the asphalt to the aggregate, the amount of liquefier can be adjusted to give any desired shelf life before the mix is to be placed, the

amount of residual asphalt from design is actually measured into the mix, and the penetration grade of the residual asphalt can be easily varied. Asphalt emulsions are advantageous in that no heat is required in the mixing process, and the emulsions can be added to damp aggregates. However, mixes made with asphalt emulsions cannot be stockpiled unless the emulsion has been specifically formulated for stockpiling purposes. Liquid asphalts can be contained in a single tank and only the standard pipelines and spray bar are necessary, whereas additional equipment is necessary for handling the liquefier for the asphalt cement and liquefier type. The choice of type of bituminous material would depend primarily on the most economical available type and on the type of equipment to be used, although the best results can probably be obtained with the asphalt-cement-and-liquefier-type binder. Table A-2 is provided as a guide to selection of the proper grade of bituminous material. The table is given in two parts, one for bitumen for mixes to be used immediately and the other for the bitumen in mixes for stockpiling for later use.

Table A-2. Selection of Bitumen

Bituminous Material	Climatic Conditions: Cold	Moderate	Hot
		Immediate Construction	
Asphalt cement penetration	120-150	85-100	85-100
Liquefier kerosene gal per ton mix	2.0	1.7	1.5
Liquid asphalts	RC-70 - RC-250	RC-250 - RC-800	RC-800 - RC-3,000
Emulsified asphalts	MS-2h SS-1h	MS-2 - MS-2h SS-1 - SS-1h	MS-2 SS-1
Tar	RT-7 - RT-9	RT-7 - RT-9	RT-7 - RT-9
		Stockpile Material	
Asphalt cement, penetration	120-150	85-100	85-100
Liquefier, gal per ton mix	4.5	3.7	3.0
Liquid asphalts	MC-70 - MC-250	MC-250 - MC-800	MC-800 - MC-3,000
Tar	RT-5 - RT-7	RT-5 - RT-7	RT-5 - RT-7
Emulsified asphalts (a)	MS-2h SS-1h	MS-2 - MS-2h SS-1 - SS-1h	MS-2 SS-1

(a) Specifically formulated for stockpile use.

g. Mix design. Several equations based on the surface area of the aggregate are available for calculating the optimum amount of bituminous material in the mix. Although these equations give an approximation of the binder content, they do not properly account for porosity of the aggregate or the compaction characteristics of the mix and, therefore, can be misleading. The following procedure is recommended for determination of the amount of bituminous material to be used in the paving mix for plant-mixed cold-laid pavements. The design procedure described subsequently for plant-mix cold-laid mixes is similar to the method for designing plant-mix hot-laid mixes for roads and streets. The laboratory equipment and test procedures are to be in accordance with MIL-STD-620, Methods 100 and 101.

(1) Bitumen contents for specimens. The quantity of bitumen required for a particular aggregate is the most important factor in the design of a paving mixture. An estimate for the optimum amount of bitumen for the aggregate to be tested must be made in order to start the laboratory tests. Laboratory tests normally are conducted for a minimum of five bitumen contents: two above, two below, and one at the estimated optimum content. One percent incremental changes of bitumen may be used for preliminary work; however, increments of 1/2 percent generally are used where the approximate optimum bitumen content is known and for final designs. The bitumen content will be determined using asphalt cement except that paving grade tar will be used in the test procedures when tar is to be the binder medium of the pavement being designed. Tar generally requires about the same volume of bitumen, but since tar is heavier than asphalt, the percentage by weight is generally higher.

(2) Proportioning of aggregates. As a preliminary step in mixture design and manufacture, it is necessary to determine the approximate proportions of the different available stockpiled materials required to produce the desired gradation of aggregate. This is necessary in order to determine whether a suitable blend can be produced and if so, the approximate proportion of aggregates to be fed from the cold feed into the dryer. Sieve analyses are run on material from each of the stockpiles. After a suitable blend has been prepared from the available materials, then samples of these materials can be processed for use in the laboratory design tests in accordance with MIL-STD-620.

h. Determination of optimum bitumen content. The optimum bitumen content will be taken as the average of the asphalt contents corresponding to the mix properties in table A-3.

Table A-3. Optimum Bitumen Content

Mix Property	Value for Determining Optimum Bitumen Content
Unit weight of mix	Peak of curve
Percent voids total mix	4 ± 1
Percent voids filled with bitumen	75 ± 5

The optimum bitumen content will be the amount of asphalt cement or tar that will be incorporated into the mix. The percent of liquid asphalts and emulsified asphalts will be corrected to give a residual asphalt content equal to the optimum asphalt content determined by the tests. When the asphalt cement-liquefier-type mix is to be used, the desired amount of liquefier will be added to the actual paving mix in addition to the optimum asphalt content determined from the laboratory design. When tar is to be used in the mix, the amount of tar will be the same as optimum value determined by the laboratory tests.

A-3. Plant control.

a. Plant operation. Three typical types of mixing plants are illustrated in appendix A of EM 1110-3-141. Typical plants include batch, continuous-mix, and dryer drum. It is generally necessary, during the operation of a bituminous paving plant, to combine aggregates from two or more sources to produce an aggregate mixture having the desired gradation. Aggregates from the different sources are fed into the aggregate dryer in the proportions required to produce the desired gradation. This initial proportioning generally is accomplished by means of a hopper-type mechanical feeder on one or more bins that feeds the aggregates into a cold elevator, which, in turn, delivers them to the dryer. The mechanical feeder is generally loaded by a clam shell or other suitable means in the proportions of aggregates desired. The aggregates pass through the dryer where the moisture is driven off and the aggregates are heated to the desired temperature. In the dryer drum mix plant the binder is added to the aggregate during drying and leaves the dryer as mixed pavement material ready for truck loading. Upon leaving the dryer of batch and continuous-mix plants, the aggregates pass over vibrating screens where they are separated according to size. When using emulsified asphalt as the binder, the dryer operation is omitted. The usual screening equipment for a three-bin plant consists of a rejection screen for eliminating oversize material and screens for dividing the coarse aggregate into two separate bins with the fine aggregate going to the third bin. When the aggregate is not dried, the fine bin screen size shall not be smaller than 3/8 inch. An additional screen is provided for further separation of the coarse aggregate in a four-bin plant. When additional mineral filler is required, usually it is stored and weighed or proportioned into the mix separately. Plant screens vary in size of opening, and the size employed is largely dependent upon the type of mixture being produced. In some cases, it may be necessary to change the size of screens to obtain a proper balance of aggregate sizes in each bin.

(1) Feeding. The aggregates must be fed through the plant uniformly, preferably by a mechanical feeder, in order to obtain efficient plant operation and to produce a mixture conforming to the desired gradation. The proper proportion of aggregates to be fed into the dryer may be determined approximately from the laboratory design. However, it is usually necessary to make some adjustments in these proportions because (a) a sieve analysis of the stockpile aggregates generally will not exactly duplicate the sieve analysis of the aggregate samples obtained for laboratory design use; (b) fines may be lost while passing through the dryer unless the equipment includes an effective dust collector; (c) aggregate may degrade in the dryer; and (d) the plant screens are not 100-percent efficient in separating of the aggregate and some fines are carried over into the coarser bins.

(2) Batch plant. The batch-type plant proportions, mixes, and dumps successive batches of the bituminous mix. These plants handle batches generally ranging in weight from about 2,000 to 6,000 pounds, with capacities varying from 40 to 300 tons per hour. Usually, the batch proportions are measured by actually weighing the prescribed quantities of the various aggregate fractions and bituminous materials into each batch. However, in some of the automatically operated plants, although the actual calibration is based on weights, the operational proportioning is accomplished by measuring the volumes of the several materials required to give these weights.

(3) Continuous-mix plant. The continuous-mix plant takes its name from the operating procedure. The ingredients are fed into the mixer, mixed, and discharged continuously at a constant rate. A small storage bin at the discharge end of the mixer holds the plant output while a loaded truck is being moved away from the discharge chute and an empty truck is being brought into position. Although the calibration of the continuous-mix plant is based on weights of the various materials going into the mix, the actual proportioning is based on the volumes of materials coming from the different feeders. The devices feeding each aggregate and the bituminous materials are interlocked to automatically maintain the proper proportions continuously. The capacities of continuous-mix plants are about the same as for batch plants.

(4) Dryer-drum mix plant. The dryer-drum type plant is a continuous-mix process but differs from the continuous-mix plant in that the aggregate and bituminous binder are mixed and dried in one operation. Aggregate gradation control is achieved in the crushing and stockpiling operation. Accurately controlled feeders proportion the aggregate from the cold bins which is conveyed to the drum. Belt scales continuously weigh the aggregate and proportion the asphalt pump

to maintain a constant aggregate-to-asphalt ratio entering the drum. The mix leaving the dryer-drum passes through a scalping screen before being conveyed to a surge bin for truck loading.

(5) Operation variables. The plant operation varies with the type of bituminous material used in the mix. For mixes with asphalt-cement-liquefier bitumen, the liquefier and asphalt cement must be introduced onto the aggregate at different times. Drying of aggregate is not necessary with asphalt emulsions, but aggregates should be heated to between 200 and 250 degrees F. prior to mixing with the other liquid types of bituminous materials. Aggregates should not be hotter than 200 degrees F. when mixed with rapid curing liquid asphalts, and not more than 250 degrees F. for mixing with the medium curing grades or asphalt cement and kerosene. The bituminous materials should be in the temperature ranges given in table A-4 when introduced into the pugmill.

Table A-4. Mixing Temperatures

Bituminous Material		Temperature
Type	Grade	Range, Degrees F.
Emulsified asphalts	MS-2	100-160
	MS-2h	100-160
	SS-1	75-130
	SS-1h	75-130
Liquid asphalts	RC-70	100-135
	RC-250	135-175
	RC-800	170-205
	MC-70	100-135
	MC-250	135-175
	MC-800	170-205
Tar	RT-5	80-150
	RT-6	80-150
	RT-7	150-225
	RT-8	150-225
	RT-9	150-225

b. Plant laboratory. A plant laboratory is necessary to insure that the aggregate is of the proper gradation and that the mix contains the prescribed percentage of bituminous material. The plant laboratory should contain the following major equipment:

(1) Sieve shaker: One hand- or power-driven mechanical sieve shaker with a capacity of not less than eight full-height 8-inch-diameter sieves.

(2) Sieves: One full-height 8-inch-diameter sieve for each of the following sieve openings: 1/2 and 3/8 inch, and Nos. 4, 8, 30, 100, and 200. The sieves should have square openings and meet the ASTM E-11 requirements of sieves for testing purposes.

(3) Extractor: One extractor suitable for obtaining bitumen content within close tolerances.

(4) Balance: One balance having capacity of 2 kilograms and sensitive to 0.1 gram.

(a) Plant calibration. The first step in starting operation of either a batch-type or continuous-mix plant is calibration of the cold feeds. This is accomplished by setting the cold feeder gate at a specific opening, operating the feeder for a given length of time or number of revolutions, catching the discharge, and determining the dry weight of the discharge. This process is repeated to develop a calibration curve for a specific feeder for a given aggregate. The procedure is repeated for each feeder and then the feeders are adjusted for the proper percentage by weight of each aggregate to be used in the mix and for the desired output of the plant in tons per hour.

(b) Selection of screens. The next step is selection of screens for the hot bins. For this it is necessary to know the capacities of the hot bins so that screens may be used that will divide the aggregate into the hot bins in proportion to the capacity of the bins. This is accomplished by taking the gradation of the combined aggregate from the cold feeder and dividing it according to the bin capacities. Generally, a slightly larger screen is used over the fine-aggregate bin than the maximum size desired in the bin. The reason for this is that the fine screens tend to clog and override into the bin of the next larger size. The plant is started in operation and aggregate is allowed to run long enough to allow the hot bins to fill to about one-half total capacity. This dry run consists of firing the dryer and allowing it to heat and starting the cold feeder, cold elevator, hot elevator, and screening unit so that hot, dry aggregates go into the hot bins. The batch-type plant is then calibrated from gradation analyses made on samples from each hot bin. The plant scales are set to weigh the correct percentages of aggregates from each hot bin and the correct amount of bituminous material to meet the job-mix formula. For the continuous-mix plant, each hot bin has an apron-type feeder that is calibrated in the same manner as the cold feeder. The apron feeder is always calibrated in terms of the revolutions of a gear shaft, which has a revolution counter attached. Also attached to this shaft is a metering pump for the bitumen. This is a positive displacement pump that delivers a constant amount of bitumen for each revolution of the pump. The speed of the pump can be varied by using different sprocket sizes. To calibrate the metering pump, the pump is run for a number of revolutions and the discharge from the pump is collected and weighed. Since the bitumen is measured by volume through the pump, a change in temperature from the desired production temperature will affect the weight per unit value. When the output of the feeders from each hot bin and the output of the bitumen pump per revolution are known, the plant is set by letting the output of the bitumen equal the desired bitumen content. The apron feeders for each hot bin are then set to produce the desired percentages of bitumen and aggregate sizes to meet the job-mix formula.

(c) Gradation control, sieve analysis. All sieve analyses are to be conducted in accordance with ASTM C 136. The gradation of the aggregates going into the paving mix must fall within the tolerances of the job-mix formula as given in the appropriate guide specification.

c. Controlling plant production. In order to insure that the plant remains in calibration and that the proper bituminous mix is produced, the following control procedures should be followed:

(1) Extraction tests. Representative samples of paving mixture are obtained twice daily for extraction tests to determine the percentage of bitumen in the mix and the gradation of the extracted aggregates. Extraction tests are made in accordance with ASTM D 2172 using trichloroethylene as the extraction solvent. Sieve analyses of recovered aggregates will be tested with procedures specified previously.

(2) Hot-bin gradations. Hot-bin gradation tests are determined on the aggregate in the fine bin at 2-hour intervals during operation. Hot-bin gradations are determined on all bins in conjunction with sampling of the pavement mixture. Washed sieve analyses are determined initially and when gradations vary to establish a correction factor to be applied to unwashed (dry) gradations. Dry sieve analyses must be conducted frequently to maintain control.

(3) Adjusting mix proportions. Mix proportions are to be adjusted whenever the above tests indicate that specified tolerances are not being met. In the case of batch plants, faulty scales and failure of operator to weigh accurately the required proportions of materials are common causes for paving-mixture deficiencies. The total weight of each load of mixture produced should not vary more than plus or minus 2 percent from the total of the batch weights dumped into the truck. Improper weighing or faulty scales may be detected readily and corrective measures taken by maintaining close check of load weights. Other probable causes of paving-mixture deficiencies due to improper plant operations are given in figure A-3.

No.	Probable Causes Of Deficiencies In Plant Mix Paving Mixtures	Bitumen content fails to check job-mix formula	Gradation fails to check job-mix formula	Poorly mixed loads	Fat, rich mixtures	lean or burned mixtures	Mixture temperature fails to check job mix	Smoking loads	Steaming loads	Overweight or underweight loads	Lack of uniformity of mixtures in loads
1	Aggregate scales out of adjustment	X	X		X	X					
2	Bridging of hot aggregate in bin		X							X	X
3	Bitumem scales out of adjustment	X			X	X				X	X
4	Lack of proper weighing by operator	X	X		X	X				X	X
5	Faulty pug mill dump gate	X	X	X	X	X				X	X
6	Bitumen temperature too high			X	X	X	X				X
7	Drum feed not uniform						X	X	X		
8	Improper dryer operation					X	X	X	X		
9	Too little bitumen	X				X					X
10	Too much bitumen	X			X						X
11	Sampling method not uniform	X	X		X	X					
12	Excessive moisture content of aggregate								X		X
13	Bin overflow pipes not functioning	X	X								X
14	Leaky bins	X	X		X	X					X
15	Segregation of aggregates in bins		X								X
16	Mixing time not uniform	X		X							X
17	Mineral filler feed not uniform	X	X		X						X
18	Aggregate temperature too high					X	X	X			
19	Temperature mechanism out of adjustment					X	X	X	X	X	X
20	Improper feed of aggregates to dryer	X	X		X	X		X	X		X
21	Overrated dryer capacity						X		X		X
22	Faulty screen operation										X
23	Overload pug mill			X							X
24	Improper set on pug mill	X	X	X							X
25	Bitumen and aggregate feed out of adjustment	X	X		X	X					X
26	Bitumen pump not functioning properly	X			X	X					
27	Not sufficient hot aggregate in storage bins	X	X								X
28	Aggregate gates not properly set	X	X		X	X					X

Items 6 to 23 incl. are applicable to all types of plants. Items 1 to 5 incl. and items 24 to 28 incl. are applicable to batch plants and volumetric plants respectively.

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FIGURE A-3. TYPES OF PAVING MIXTURE DEFICIENCIES AND PROBABLE CAUSES